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# ANALYSIS OF PROBLEMS ENCOUNTERED IN R&D PROJECT MANAGEMENT

Roy Poust and Irwin Rubin

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# Analysis of Problems Encountered in R&D Project Management

by

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## ABSTRACT

The study reported in this paper is an analysis of 32 research and development projects performed by industrial concerns under government contracts. Specifically, it presents a typology and quantitative analysis of problems encountered in performing government-supported projects in the aerospace and electronics industries.

The rankings of frequencies of project problems encountered by project managers were found to be inversely correlated with the rankings of importance of problems associated with their position. Laboratory managers' problem rankings were also found to be inversely correlated. This implies that (1) project managers do not spend their time on problems they consider to be important, and (2) laboratory managers do not report their important problems as being the same as those project problems which come to the attention of top management.

The rankings of frequencies of problems encountered by project managers and laboratory managers were found to be significantly correlated. The rankings of importance of problems associated with the job positions of project managers and of laboratory managers were not related. The rankings of frequencies of problems encountered by project managers and government technical monitors were found to be correlated, but the frequency rankings of laboratory managers and government technical monitors were not related.

A general problem category typology was developed from the data submitted on each project.

# INTRODUCTION

Project and laboratory managers in private industrial R&D laboratories are becoming increasingly concerned with the effective control of their projects and programs. Total package procurement concepts, cost effectiveness analyses, cost reduction programs, cost and economic information systems, PERT time, PERT COST, configuration management programs, value engineering programs, weighted guidelines, approaches to profit determination, and formal contractor performance evaluation procedures are just a few of the new project control and major weapons acquisition techniques designed and implemented by the government and/or private industry in the last decade. Customer requirements and restrictions on research or development contracts are greater in number and more detailed than ever before. The project managers' and laboratory managers' own organizations exert great pressure on them to gain more effective control over technical, schedule, and cost requirements. The Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) are using incentive contracts and fixed price contracts (with incentives applying to both technical and managerial performance) in an effort to bring their programs to completion on time and within budgeted costs. More and more government R&D contracts are of the fixed price or incentive type (e.g., cost plus incentive fee, fixed price incentive, firm fixed price, etc.). The costs and penalties associated with losing control of a project are high, and the future of many companies and the careers of many individuals are determined on the basis of the performance of these projects. The

search for effective and efficient project control techniques will not be a successful one unless the critical problems are first identified and accurately defined.

The objectives of this study are fourfold in nature. First, to identify critical problems encountered in managing government-funded R&D projects. Second, to determine whether or not those problems considered important by project and laboratory managers were actually critical to the control of their projects. The viewpoints of both the government (customer) and the private industrial contractor (R&D laboratory) are examined. Developing a general problem category typology that would be useful in identifying and categorizing problems project managers and laboratory managers face is a third goal of the study. The final objective is to make a comparative analysis of the problem rankings of project managers, laboratory managers, and government technical monitors.

Very little has been written concerning either the types of problems encountered by project and laboratory managers while working on government-funded R&D projects, or the frequency of occurrence and the degree of importance of different types of project problems. There have been a few case studies done (Kennedy and Hansen, 1964), but none that describe or explain the types of problems encountered on a large sample of projects. Field (1966) studied the organization and work relationships of various groups that relate to the project manager in the process of solving project problems. However, his study was

limited to the Saturn V and Saturn 1 - B programs at Marshall Space Flight Center, Huntsville, Alabama. Also, he studied only the government's project management organization (as opposed to both the government's and private contractor's organizations). Another difficulty arises from the fact that Field's problem categories and broad problem definitions are difficult to generalize to other projects.

Straight (1965) analyzed functional, project and matrix-overlay organizations in the research and development industry. He found that technical performance was the primary criterion for judging successful performance from both the government's and the contractor's standpoint. Schedule performance and cost performance were the second and third ranked criteria for measuring successful performance. Based on this study, then, it might be reasonable to assume that technical problems would be of critical importance in determining whether or not a project's performance would be judged successful (by both the customer and the contractor).

Peck and Scherer (1962) basically concern themselves with three types of problems involving: cost, quality (technical performance and reliability) and time (schedule problems). This problem typology serves Peck and Scherer's purposes well, but it does not cover many project problems encountered by project managers and government technical monitors. Also, their sample is based on twelve weapons acquisition programs that were all "top priority" in nature. The problems encountered in these projects may well be atypical of the R&D industry in general.

Baumgartner (1963) has written one of the few comprehensive books on the subject of project management in which he describes some of the planning and control problems that face the project manager and some of the techniques that have been developed for their solution. Baumgartner's problem categories include the following: obtaining and maintaining project control, developing in-house and subcontractor project teams, managing funds and costs, maintaining profits, maintaining customer relations, and forecasting future difficulties. Although these categories are more extensive than any others found in the literature, they have some major shortcomings. First, the categories are not mutually exclusive and hence, it is not clear whether some problems fall into one category or another. Secondly, project managers seem to have many problems that are not included in his typology, such as obtaining and keepting competent people, resolving conflicts generated by contract changes and amendments, etc. Finally, he never clearly defines his problem categories. A typology or problem category classification scheme is needed that is based on systematic collection of information from a large sample of people. It should take laboratory management problems into consideration, as well as project management problems.

## RESEARCH METHODS

Information on each of the 32 projects included in the study was obtained from three sources: within the contractor's organization data were collected from the project manager and the laboratory manager;

within the customer's organization data were gathered from the government technical monitor. The projects were selected on the basis of three criteria:

a. All were R&D contracts awarded by a government agency (or industrial prime in several cases) to an industrial firm.

b. All were over one million dollars in total value (excluding follow-on production work).

c. All were very recently completed or rapidly nearing completion.

The project managers, the laboratory managers, and the government technical monitors all described the organization, operations of the project group, and the critical problems that occurred during the life of the project.

Research Instruments

The questions for this study were taken from an exhaustive project questionnaire developed by Donald G. Marquis and his associates in the M.I.T. Research Program on the Management of Science and Technology. Valuable use was also made of an extensive report by two members of the Harvard University Weapons Acquisition Research Project (Peck and Scherer, 1962). Six specific questions, all concerning problems encountered during the life of a project, were used. The project manager was asked three of the questions, the laboratory manager two, and the government technical monitor one. The final set of problems categories was derived from the responses obtained from these six questions on each of the 32 projects.

The projects studied were funded by five government agencies. Nine were supported by the Air Force, fourteen by the Navy, one by the Army, six by the National Aeronautics and Space Administration, and one by the Federal Aviation Agency. One project was classified and the name of the funding agency could not be determined. The twenty-nine firms possessing the thirty-two contracts in the sample (General Electric had three contracts and Bell Aerospace two) are large corporations in the aerospace and electronics industries. The laboratories or engineering facilities in which the projects were performed are located in all regions of the country.

The 32 projects ranged in size from one million dollars to sixty million dollars with a mean of $8,053,000, and in length from one year to five years with a mean of two years and four months. The amount of work to be accomplished varied greatly with each project. Almost all of the projects required advances in the "state-of-the-art" in a technological field such as advanced radar systems, microminiaturization of electronics modules, electronic data processing interfaces with telemetry systems, etc. The projects studied were more developmental than fundamental research and almost all of the contracts were performed under some form of cost-plus contract.

# RESULTS

## Project Manager Problem Analysis

The major problems encountered during the life of a project were reported by the project manager when he answered the following question:

> "Because of the nature of R&D work, the problems that arise during the life of a project are many and varied. Using the famework provided, would you please trace the history of the major problems (other than specific technical problems) you encountered during this project. Please indicate anything which resulted in a contract change."

Project managers listed technical problems more frequently than any other problem category in terms of total number of times the problem type was encountered. This is particularly interesting because the question specifically asked the project managers to list problems "other than specific technical problems". It appears that technical problems were so important that the project managers felt that they should list them despite the instructions. Schedule problems ranked second and cost, contractual, and subcontractor problems were ranked third, fourth, and fifth, respectively. These five problem areas (technical, schedule, cost, contractual, and subcontractor) represent 91% of the total number of problem responses. Personnel problems, organization and coordination problems, and miscellaneous problems make up the last 9%. The following ranking of problems: (1) technical, (2) schedule, and (3) cost, agrees with Marquis' and Straight's (1965) project performance rankings. They studied criteria used in evaluating project performance measures and

found that the project managers ranked technical, schedule, and cost performance first, second, and third in terms of importance.

Project Managers' Actual Allocation of Time

As a check on the results obtained from the above question, and in order to determine how project managers actually allocated their time, the following question was asked:

> "Out of 170 hours in a typical month, how much time did you spend in the following areas?"

This question was a structured one with a limited number of fixed alternatives as given below:

a. Subcontractor problems
b. Getting future proposals and new business
c. Personnel problems
d. Schedule problems
e. Customer problems
f. Technical problems
g. Contractual problems
h. Organization and coordination problems
i. Reading and professional development

Project managers directed the largest percentage of their time to technical problems. They spent, on the average, 26.7% of their time on technical problems. This is consistent with the number of times technical problems were mentioned by the project managers when they responded to the previous question. The next largest segment of a project manager's time was devoted to schedule problems, which also ranked second on the previous question, they did not even mention customer problems.[1] The project managers devoted 10.7% of their time

[1] It is possible that the one project studied for each project manager was not typical, in terms of the problems they generally encounter, although this appears somewhat unlikely considering the restrictions used in selection of the projects for the sample.

to contractual problems. Subcontractor problems took 7.2% of the project manager's time. Project managers devoted approximately 80% of their total effort to technical, schedule, customer, contractual, and subcontractor problems. New business problems, personnel problems, organization and coordination problems, and miscellaneous problems accounted for roughly 20% of the project manager's time.

An internal check on the problem category rankings made by the project managers was desired so that the validity of the problem rankings might be tested. A Spearman rank correlation was performed (one-tailed test $r_s = .64$, significant at $p < .05$ level) between problems ranked according to the actual allocation of time by project managers versus the number of times they mentioned specific problem types in recounting their project's problem histories. Technical, schedule, contractual, and subcontractor problems all rank high in terms of the number of times they were encountered and the amount of time project managers allocated to each category. Although project managers spent a substantial portion of their time on customer problems (14.6%), they did not mention them in recounting problems they had run into. The disproportionate amount of time spent on this apparently infrequent problem may be an indication of the inherent difficulty of the particular problem.

Important Problem Categories

In order to determine whether project managers actually spent their time on problems they considered to be important, the following question was asked:

> "What do you consider the most important problems of a project manager?"

The project managers indicated that finding effective control methods for handling cost, schedule, and technical requirements was the problem they "considered most important". They included in this problem category the implementation of the control methods along with finding "optimal" trade-offs between cost, schedule, and technical requirements. Motivating people to continually do a good job was the second most frequently mentioned problem category. Obtaining and keeping competent people was ranked third.

Finding effective control methods for cost, schedule, and technical requirements was the first mentioned response in 11 cases which might indicate that the project managers considered this problem to be the most important, regardless of the number of times they encountered it.

It was anticipated that the project manager's job problems would correspond rather closely to the actual problems encountered in the projects. Quite surprisingly, the two problem rankings are inversely correlated. ($r_2$ = -0.67, significant at p .05 level).

Although the project managers indicated in retrospect that technical and schedule problems were their most frequent problems, they gave technical and schedule problems quite low ratings when they ranked their job problems. Schedule problems were ranked sixth in importance and technical problems tenth. The project managers, however, never mentioned in their project histories, that finding effective control methods for cost, schedule, and technical requirements was either an important problem or a problem which occurred frequently. They also failed to mention that "obtaining and keeping competent people" and motivating these people were important problems.

One possible explanation for the discrepencies is that although technical, schedule, cost, customer, and contractual problems are frequently occurring problems for project managers, they are not important problems (relative to other problem categories, such as obtaining and keeping competent people). However, even this is not an adequate explanation because the project managers indicated that they actually spent most of their time on technical, schedule, customer, and contractual problems. Consequently, the basis paradox remains...project managers do not spend time on problems they consider to be generally important.

One final explanation is that those problems reported to be important are either extremely difficult or insoluble problems. Extremely difficult problems would take up to much of their time (they still have to "fight fires"), and hence, they are not attacked. The problems that they feel they can solve are those that take up the greater portion of their working day. This explanation, however, has not been tested empirically.

Laboratory Manager

A frequency count of the critical problems encountered while working on a project was recorded by the laboratory manager when he answered the following question:

> "What critical problems in the project became the concern of higher management? How were they solved?"

The laboratory managers mentioned cost problems more frequently than any other problem category. Cost problems occurred 27.8% of the time. Technical problems ranked second. Schedule problems and subcontractor problems were also encountered fairly frequently. Personnel problems ranked fourth in terms of total number of responses. The following five problem areas-- cost, technical, schedule, subcontractor, and personnel-- represent approximately 80% of the total number of problem responses. Contractual problems, organization and coordination problems, customer problems, and miscellaneous problems represent the last 20% of the aggregated problem responses.

The laboratory managers in their response to the following question:

> "What do you consider the most important problems of a laboratory manager?"

most frequently indicated that obtaining and keeping competent people was their most important problem. "Seeing that people are working effectively and efficiently" was the second most frequently mentioned problem category. This problem meant, in essence, that the laboratory manager was always seeking a productively good match between the specialized skills of various members of his staff, and R&D laboratory requirements. The third most frequently mentioned problem, motivating people to continually do a good job, received 12 responses. Personnel problems and getting future proposals and new business were ranked fourth and fifth respectively. These five problem categories represent approximately 75% of the total number of problem responses. Schedule problems, cost problems, finding effective control methods, and

miscellaneous problems represent the last 25% of the total number of responses. It is interesting to note that the top four problem categories are all "people problems". This was not the case for the project managers who were more concerned about technical, schedule, and cost problems.

The laboratory managers reported "obtaining and keeping competent people" as their first mentioned problem 12 times. This might be an indication that the laboratory managers consider this problem to be the most important, regardless of the number of times they encounter it on projects. Since the laboratory manager's promotions are based, at least to a certain extent, on how well he handles the problems he or his project managers encounter, it seemed reasonable to predict that the laboratory manager would consider his major problems as being identical, or nearly identical, to those he actually encountered. However, the laboratory manager's project problem listing and job problem listing are negatively (inversely) correlated, ($r_2 = -.61$, significant at $p < .05$) as were the project manager's job and project problem listings.

Although the laboratory manager's responses indicated that cost and technical problems were historically their most frequently mentioned project problems, both these categories received low ratings when the laboratory managers ranked the importance of their job problems. Technical problems were ranked seventh and cost problems ninth. The laboratory managers, however, rarely indicated that problems such

as "obtaining and keeping competent people," "seeing that people are working effectively and efficiently," and "motivating people to continually do a good job" either became the concern of higher management or actually were critical.

It might be that these project problems which became the concern of higher management were insoluble problems for the laboratory manager for one reason or another. Consequently, he did not report these problems as being important. On the contrary, those problems that he could solve might be the ones that he thought were important. However, the laboratory manager is partially evaluated on whether or not he solves important laboratory and project problems. Again, a paradox remains: laboratory managers do not consider their important job problems as being the same as those project problems which come to their attention.

Government Technical Monitor

The government technical monitors in recording frequencies of critical problems faced by the contractor's project team mentioned technical problems more often than any other problem category. Schedule problems were ranked a poor second, along with interface technical problems. Contractual problems and subcontractor problems were tied and ranked third in frequency. These five categories represent 98.3% of the total number of problem responses. Technical problems completely dominate all other problem categories. This is consistent with the Marquis and Straight (1965) finding that technical performance was the

primary criterion employed by the government in their evaluation of the project. Thus, the contractor's project manager and the government technical monitor agree that technical problems are the most critical problems they face during the life of a project.

Although the government technical monitors do not mention cost problems at all, it may be that they see cost problems as being caused by technical or schedule problems.

Comparative Analysis of Problem Rankings

A comparative analysis of both the project and the job problem rankings of project managers and laboratory managers has raised a number of interesting points. Project managers and laboratory managers largely agree on what types of critical problems actually occurred on their projects. Technical, schedule, and cost problems are all critical and they are mentioned frequently. Project managers and laboratory managers do not agree on the types of important problems they encounter on their jobs. Two problem categories, "seeing that people are working effectively and efficiently," and "finding effective control methods," differed by five ranks in the two problem listings. These differences may be attributed to the different roles and responsibilities of the two positions.

Surprisingly, only one of the eight problem categories has a difference of zero. Again, the job of the project manager and the job of the laboratory manager may vary due to inherent differences in their jobs. One would expect the project manager to be primarily concerned

about controlling (technical, schedule and cost parameters) his project. The laboratory manager, however, most likely has other projects over which he must preside, in addition to the administrative functions his position entails (such as obtaining and keeping competent people for his R&D laboratory). Also, the differences in the authorities held by a project manager and a laboratory manager may be large. Straight (1965) found that the authorities most frequently reported by project managers were the initiation of work in support areas and changing schedules for project subactivities. Laboratory manager authorities would most likely be much more extensive than these.

Project managers and government technical monitors generally agree on the types of project problems they encounter. Their project problem rankings are moderately correlated. Technical and schedule problems are ranked first and second respectively, by both the project managers and the government technical monitors. However, "cost problems" ranked third by the project managers but sixth by the government technical monitors. The low ranking of cost problems by government technical monitors should not necessarily be interpreted as meaning that the government technical monitors considered them unimportant. On the contrary it may well be that the technical monitors felt that if technical and schedule problems were found quickly and solved quickly, there would not be many cost problems. Another explanation is that the same problem may have been classified as a technical problem by the government technical monitor, but as a cost problem by the project manager.

Laboratory managers and government technical monitors do not agree on the types of project problems they encounter. Their project problem rankings are not related. The government technical monitor might now understand why he may have difficulties communicating, to the laboratory manager, the government's views on problems encountered on the projects the laboratory manager oversees. Again, there is a significant difference in the rankings of the problem category "cost problems." The laboratory manager, like the project manager, ranked cost problems high (first), but the government technical monitor ranked cost problems sixth. The R&D laboratory manager must stay reasonably within his budget, and consequently, cost problems may be paramount. The reason for the low ranking of cost problems by the government technical monitor has been discussed above.

Even though all but one of the projects were of the cost plus fixed fee type (CPFF), it is interesting to note that profit, per se, was never mentioned as a problem by either the contractor's laboratory manager or project manager.

## CONCLUSIONS

Project managers ranked technical, schedule, and cost problems first, second, and third, respectively, in terms of the total number of times they encountered these problems. The project manager indicated that they spent most of their time on technical problems, allocating somewhat less time to schedule and customer problems. The

project managers thought the following three problems (job problems) were generally most important to them: (1) finding effective control methods (for technical, schedule, and cost requirements) and implementing them properly, (2) motivating people to continually do a good job, and (3) obtaining and keeping competent people. The Spearman rank correlation calculation between the project managers' project problem listings and job problem listings indicated that the two lists were inversely correlated. Evidently, project managers do not spend time on problems they see as being generally important.

Laboratory managers revealed that (1) cost, (2) schedule, and (3) technical problems were the three most critical problems (project problems) they encountered that eventually became the concern of higher management. They thought the following problems (job problems) were their most important ones: (1) obtaining and keeping competent people, (2) seeing that people are working effectively and efficiently, and (3) motivating people to continually do a good job. The laboratory managers' project problem listings and job problem listings were inversely (negatively) correlated. Laboratory managers did not consider their important problems to be the same problems that came to the attention of top management.

Government technical monitors ranked technical and schedule problems first and second, respectively, in terms of the number of times each type of problem was encountered. Contractual and subcontractor problems ranked third (tie).

Table I

SUMMARY PROBLEM CATEGORY MATRIX

| Problem Categories | Project Manager | | | Laboratory Manager | | Government Technical Monitor |
|---|---|---|---|---|---|---|
| | Job Problems N=36 | Project Problems N=28 | Allocation of Time N=30 | Job Problems N=33 | Project Problems N=32 | Project Problems N=26 |
| Technical problems | | 1 | 1 | | 2 | 1 |
| chedule problems | 4* | 2 | 2 | | 3* | 2 |
| Contractual problems | | 4 | 4 | | 5 | 3* |
| Subcontractor problems | | 5 | 5 | | 3* | 3* |
| Cost problems | | 3 | | | 1 | |
| Personnel problems | | | | 4 | 4 | |
| Organization problems | 5 | | | | | 4 |
| Customer problems | 4* | | 3 | | | |
| Getting new business | | | | 5 | | |
| Finding effective control methods | 1 | | | | | |
| Obtaining competent people | 3* | | | 1 | | |
| Motivating people | 2 | | | 3 | | |
| Seeing that people work effectively | | | | 2 | | |
| Initially designing program | 3* | | | | | |

*Ties

NOTE: 1 = Most Important, 2 = Next most important, etc.
(most frequent) (next most frequent)

The first objective of this study, the identification of critical problems, was successfully met. The results of the second objective, determining whether or not the problems that project managers and laboratory managers considered as being important were actually critical proved rather startling. Project managers and laboratory managers do not spend their time on problems they report as generally being important. It appears that their role conception and their actual job problems do not mesh.

The third objective was to construct a general problem category typology that might be useful in finding and categorizing problems project managers and laboratory managers encounter. The summarized typology is illustrated in Table II.

Finally, project manager and laboratory manager project problem category rankings were found to be correlated. Project managers and laboratory managers largely agree on the types of critical problems encountered on their projects. However, project manager and laboratory manager job problem category rankings were not related.

The next step for future research in this area might take one of three possible directions. First, the following question might be examined: how do project managers, laboratory managers, and government technical monitors solve (or try to solve) the problems they identify and define (which have been categorized here)? The second approach would be to try to relate the above-mentioned problem categories to project performance. One final approach would be to determine whether or not the nature of the problems differed with:

a. Size of contract (in dollars) b. Amount of subcontracted effort
c. Utilization of PERT time or PERT/COST

Table II

GENERAL PROBLEM CATEGORY TYPOLOGY

| | | |
|---|---|---|
| 1. | Technical problems | Project Problem Typology |
| 2. | Schedule problems | |
| 3. | Contractual problems | |
| 4. | Subcontractor problems | |
| 5. | Cost problems | |
| 6. | Organization and coordination problems | |
| 7. | Personnel problems | |
| 8. | Customer problems | |
| 9. | Getting future proposals and new business | |
| 10. | Finding effective control methods for technical, schedule, and cost requirements, and implementing them properly | Job Problem Typology |
| 11. | Motivating people to continually do a good job | |
| 12. | Obtaining and keeping competent people | |
| 13. | Defining the problem (specifying scope) designing the program, and freezing the design (configuration) early | |
| 14. | Getting authority to draw people into the project from outside the project team when necessary | |
| 15. | Finding time to keep up to date, technically and professionally | |
| 16. | Seeing that people are working effectively and efficiently: productively good match between skills and requirements | |
| 17. | Making adequate long-range plans | |

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